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MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS SAN GABRIEL RIVER LOWER BRAZOS RIVER SYSTEM TEXAS

Public Health Service
Dallas, Texas

July 1960

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MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

SAN GABRIEL RIVER

LOWER BRAZOS RIVER SYSTEM

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Fort Worth, Texas

JULY 1960

38

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LOWER BRAZOS RIVER SYSTEM

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INTRODUCTION

General

In a letter dated June 8, 1959, the District Engineer, Fort Worth District, Corps of Engineers, asked for the views and recommendations of the Public Health Service on present and prospective needs for municipal and industrial water supply for Georgetown, Taylor, and Granger, Texas. The Public Health Service was also asked to determine the desirability of meeting these needs from the Laneport project located at mile 29.1 of the San Gabriel River. At a meeting held in the Southwestern Division Office of the Corps of Engineers on December 22, 1959, the decision was made to base the study on proposed M. & I. storage at two upstream sites on the North San Gabriel and South San Gabriel Rivers instead of the Laneport site. At the same time, it was decided that the scope of the study should be broadened to include investigation of downriver needs for water supply. As the work progressed, the desirability of approaching the problem from a regional viewpoint became apparent.

This report, for the San Gabriel River, is one of a series of three companion reports on projects being studied for the tributaries of the lower Brazos River. Other reports of the series will be concerned with the Navasota River and Yegua Creek. These projects are related from a water supply standpoint, in that a common market for municipal and industrial water will exist in the lower Brazos River Basin.

This study was made in accordance with the provisions of the Memorandum of Agreement dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, to provide assistance in implementing the Water Supply Act of 1958.

Acknowledgments

Listed below are the names of individuals and organizations who provided information necessary to the preparation of this report. Their cooperation and assistance are gratefully acknowledged.

Geological Survey, U. S. Department of the Interior, Austin, Texas

U. S. Study Commission - Texas, Houston, Texas

Texas State Department of Health, Austin, Texas

Brazos River Authority, Waco, Texas

City officials - Georgetown, Texas

City officials - Granger, Texas

City officials - Taylor, Texas

Freese, Nichols, and Endress, Consulting Engineers, Fort Worth, Texas

William F. Guyton and Associates, Consulting Ground Water Hydrologists, Austin, Texas

E. Jack Turner, General Water Superintendent, Dow Chemical Company - Plant at Freeport, Texas

R. Sugt, Aluminum Company of America - Plant at Rockdale, Texas

SUMMARY AND CONCLUSIONS

Summary

1. This report is concerned with questions of water supply storage on the San Gabriel River, a tributary of the Brazos. Water requirements are given in two parts -- namely, the local area in the San Gabriel watershed, and the overall area of the lower Brazos River Basin, from Waco to the Gulf.

2. The projected water requirements for the local area, consisting of the cities of Georgetown, Taylor, Thrall, and Thorndale are 8.2 mgd by the year 2010. Of this amount, it is probable that the 2.7 mgd of projected need by Georgetown will be supplied by ground water from the Edwards formation. 7/

3. For the lower Brazos area as a whole, it is projected that about 1,102 mgd will be needed by 2010.

4. The aggregate firm yield from surface reservoirs, existing and proposed, totals slightly over 510 mgd. The maximum capability of ground water in the area is unknown, but is believed to be on the order of 50 mgd.

5. The deficiency of supply to future demand indicated above, is partially offset by the fact that the figures represent gross takeout from sources, a portion of which will be returned to the stream for subsequent re-use. Nevertheless, additional measures will be required to increase the dependable supply if growth is to occur as projected. In this connection it may be noted that a regulated surface supply of 510 mgd is a small part of the average annual runoff of about 4,600 mgd.

Conclusions

1. Storage for water supply, in the maximum amounts which can be economically provided, should be included in all projects planned for the lower Brazos River system.

2. The quality of San Gabriel River water is satisfactory for municipal and industrial water supply purposes. The maintenance of acceptable stream

quality in the main stem of the lower Brazos is a problem which calls for careful attention by the responsible agencies. Additional information on this problem is needed and should be provided by the studies now in progress for the U. S. Study Commission - Texas.

3. Based on the economic analysis of a regional alternative plan for water supply, the average present values of benefits are shown below the water supply storage of the five reservoirs considered in this study. Further details are given in the last chapter of this report.

Reservoirs	Average Annual Present Value	Yield (mgd)	Present Benefits (¢/1000 gal. of Yield)
Stillhouse Hollow	$ 515,000	63	2.24
Somerville	414,000	34	3.34
North San Gabriel	284,000	19	4.10
Millican	826,000	226	1.00
South San Gabriel	120,000	11	2.99
Sum or Average	$2,159,000	353	1.68

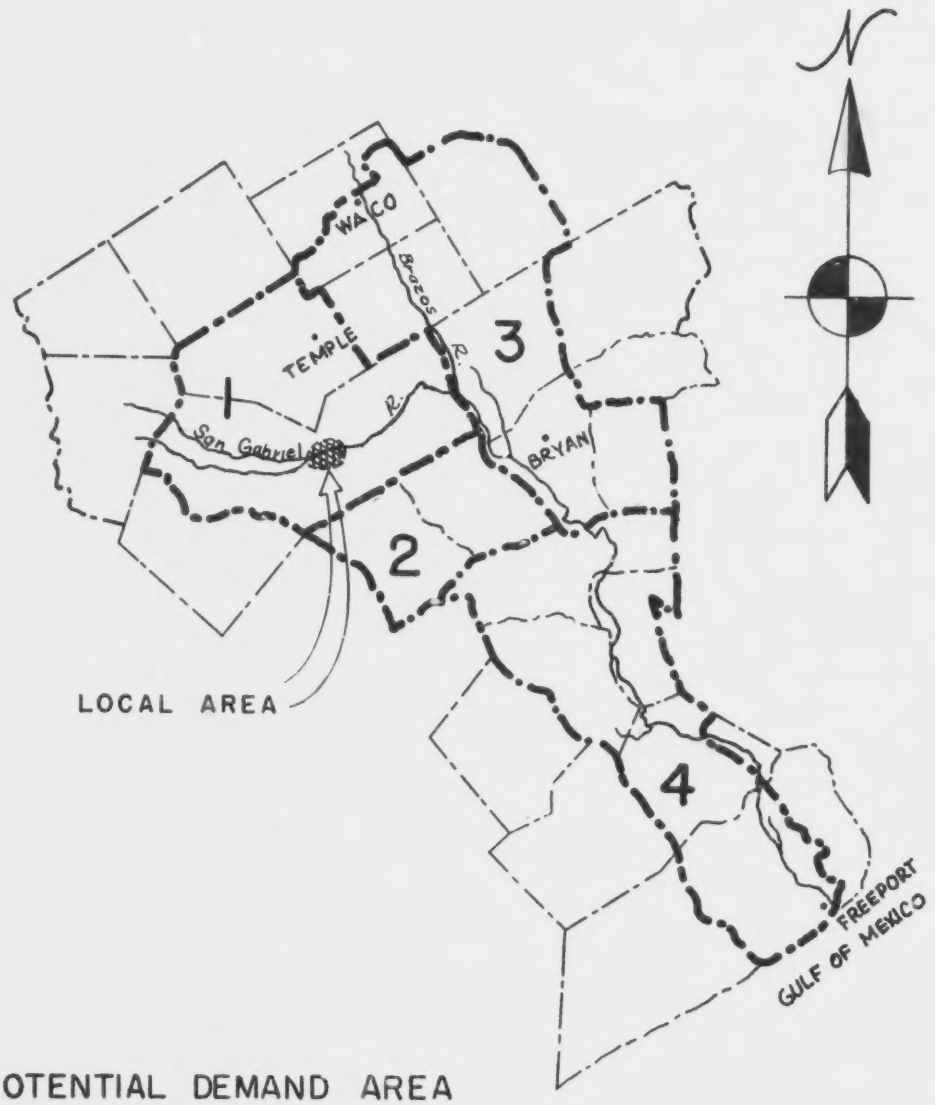
THE STUDY AREA

General Description

The two dam sites on the San Gabriel are located approximately three miles west of Georgetown, Texas, on the North and South Forks of the river. Their locations and the total area encompassed by this study are shown on Figures 1 and 2. The boundary was chosen so as to include the entire area which might be served, through one integrated plan, from reservoirs in the San Gabriel River watershed, Millican Reservoir on the Navasota River, Somerville Reservoir on Yegua Creek, Stillhouse Hollow Reservoir on the Lampasas River, the existing Belton Reservoir on Leon River, and the enlarged Lake Waco. Probably the major water demand centers of this area will develop in the vicinities of Waco and Freeport; therefore, it was decided to make the length of the study area run roughly from Waco in the north to Freeport on the southern coast. The east-west boundaries generally follow the boundary of the Brazos River Basin with consideration being given to the political boundaries which nearly coincide with this basin boundary. It was desirable to make the total study area boundary follow county or precinct lines in order to facilitate the use of U. S. Bureau of Census population data.

The total study area includes Limestone, Falls, Bell, Williamson, Milam, Robertson, Brazos, Grimes, Burleson, Washington, Waller, and Austin Counties. Also included are portions of McClennan, Lee, Fort Bend, and Brazoria Counties.

The local area, as shown on Figure 2, includes those cities immediately downstream from the reservoirs being studied. Specifically, these cities are: Georgetown, Round Rock, Taylor, Thrall, Thorndale, and Granger. Round Rock apparently will not need an additional water supply source. The existing ground water supply there seems adequate to meet all expected future needs. Granger is excluded from the detailed determination of local water requirements because it was found that the population of this city has been declining and probably will continue to decline. The other cities mentioned above were included in this study for two reasons: (1) their apparent need for additional water supply sources beyond what they have developed at present, and (2) the possibility that water from the project(s) under study could be supplied directly to these cities through a pipeline or pipelines. The relative locations of the local area and the total study area are shown on Figure 1.



POTENTIAL DEMAND AREA
LOWER BRAZOS RIVER
NO SCALE

VICINITY MAP

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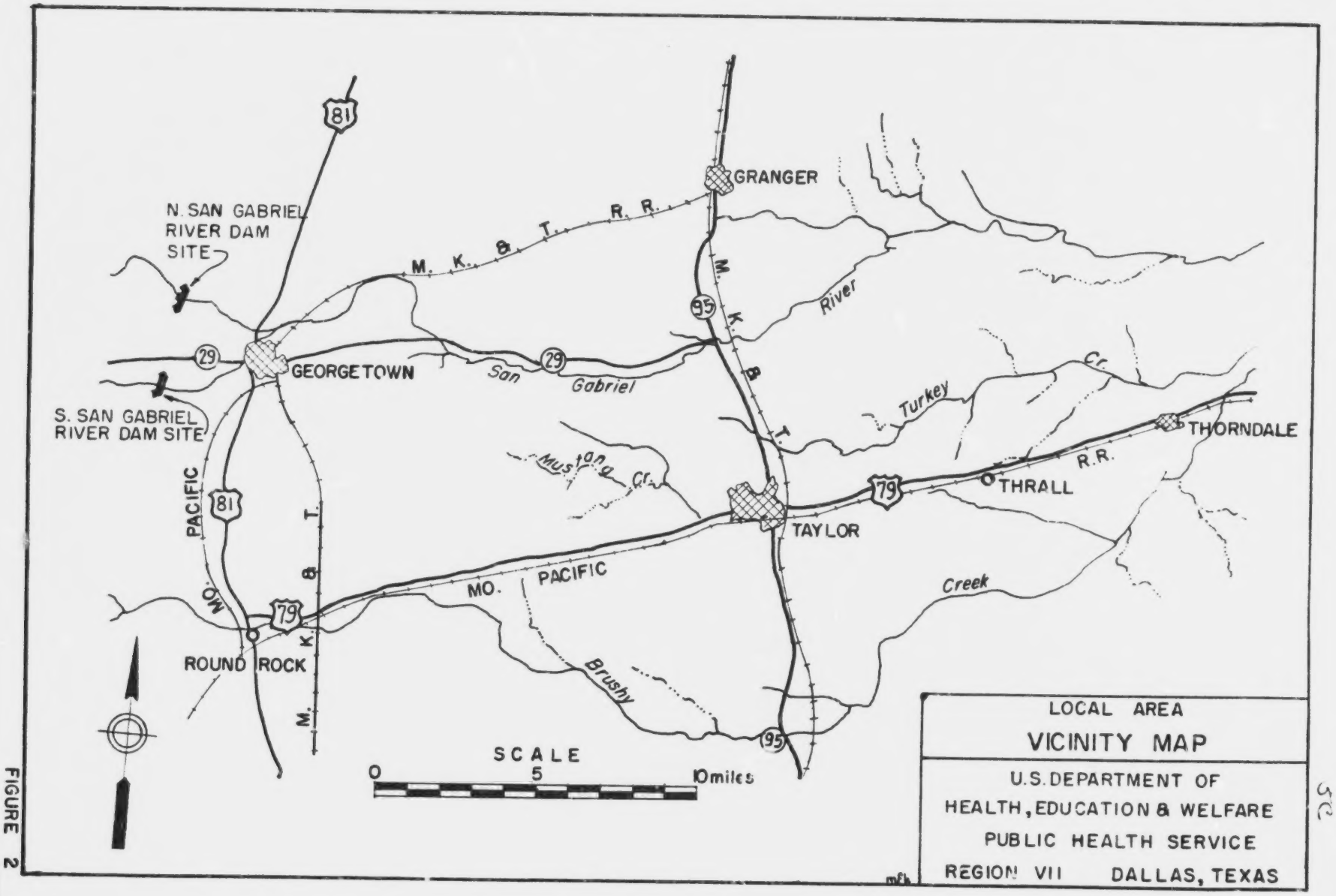
FIGURE 1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GRANGER
N. SAN GABRIEL RIVER DAM SITE
M. K. & T. R. R.
M. K. & T.
95
River
29
GEORGETOWN
San Gabriel
Cr.
Turkey
S. SAN GABRIEL RIVER DAM SITE
THORNDALE
R.R.
Mustang Cr.
79
THRALL
PACIFIC
81
M. K. & T.
TAYLOR
MO. PACIFIC
Creek
79
ROUND ROCK
Brushy
95
SCALE
0 5 10miles
LOCAL AREA
VICINITY MAP
U.S. DEPARTMENT OF
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PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 2

Description of Local Area

The San Gabriel River traverses the local area from west to east where it flows into Little River, which in turn discharges into the Brazos River. The maximum discharge of the San Gabriel River was recorded by the U. S. Geological Survey on September 10, 1921, at their gaging station 1 3/4 miles northeast of Georgetown; this discharge was 160,000 cfs. The river has also been dry for periods of three or four days' duration on several occasions. However, these dry spells have been infrequent because the San Gabriel River is spring-fed. The average flow in this river for the period of 1934-1957 has been 130 cfs. Several smaller streams (Brushy Creek, Mustang Creek, and Turkey Creek) also cross this local area from west to east.

The terrain ranges from hilly in the western portion to level in the eastern part. The soil type varies from a thin limestone soil in the west to a blackland soil in the eastern section.

The climate creates an environment favorable for the growing of plants about 255 days per year.9/ The mean annual temperature is approximately 66 degrees and the normal annual rainfall of this area is approximately 33 inches.9/

The economy of the area is predominately agricultural. There has been a steady decrease in the farm population, number of farms, and cropland harvested. The farm population is decreasing due to the increasing mechanization in farming. However, with relatively greater profitability in livestock production, cattle ranching and dairy farming are replacing field crop production.

With an increased national demand for livestock products, the agricultural economy of the area is expected to stabilize and the agriculture population will cease to decline and will level off.

The economy of the remaining area reveals signs of modest development in the activity of industry and the extracting of minerals. Income to the area is derived from limestone quarrying, the production of aluminum, a small amount of oil production and coal mining.

The aluminum plant depends on coal to produce its necessary electrical energy. With abundant deposits of coal, a significant increase in the number of mining employees will occur; however, due to mechanization in this industry, the level of employment in mining should stabilize by 1975. There will be a decrease in oil production employees, caused by the depletion of oil deposits; therefore, the total number of employees in these industries should show a decrease in the future.

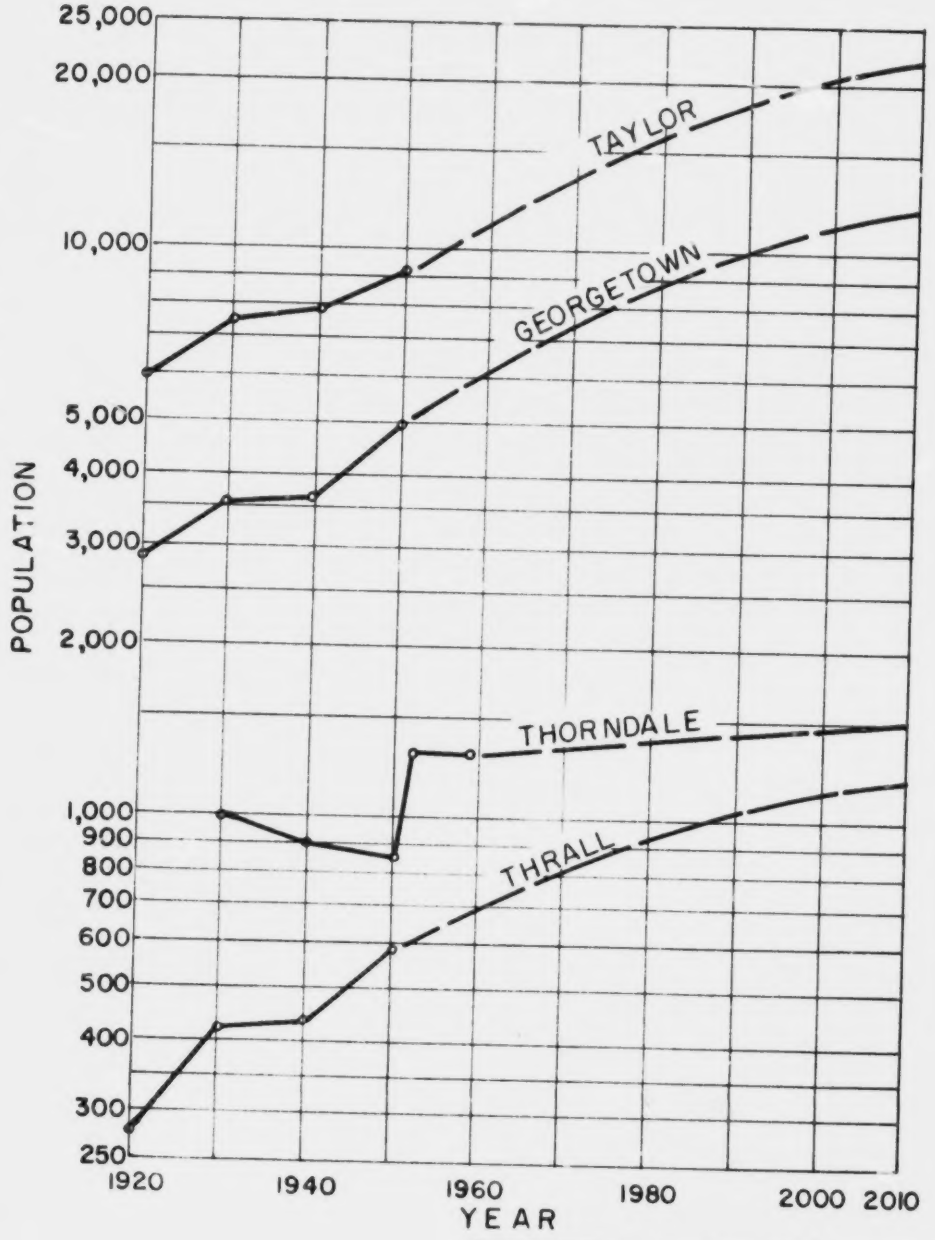
With the presence of excellent livestock production, the potential for milk and poultry industries exists. These industries may take advantage of the existing markets near the study area.

Transportation facilities in this local area are reasonably good, but not exceptionally better than many other places in the state. U. S. Highway 81 runs north and south through this area, while U. S. 79 runs east and west. The Missouri, Kansas and Texas Railroad Company and the Missouri-Pacific Railroad Company have lines that run through this area. Commercial air transportation by scheduled airlines is available in Austin.

The population of this area was approximately 30 per cent urban in 1950. Urbanization has been increasing over the past years and probably will increase in the future. This trend is partially caused by the in-migration of people from the adjacent rural areas. However, not all the population leaving the farms goes to immediately adjacent municipalities; a portion of these people migrate to cities outside this local area. This explains why the total population of the area has been decreasing while the urban population (in absolute numbers and percentage of total population) has been increasing.

The historical and anticipated populations for Georgetown, Taylor, Thrall and Thorndale are shown on Figure 3. The expected growth curves shown for Taylor, Georgetown, and Thrall were based on historical growth, field investigations, and on projections [2,3] made by the Bureau of Business Research of the University of Texas for the city of Taylor and the Austin Trading Area. Thorndale's population growth has been, and will be, affected by the aluminum plant located nearby. During the construction of the aluminum plant, the population of Thorndale was greatly increased. It is our opinion that, with an ample water supply and because of the presence of the aluminum plant, Thorndale will grow as depicted on Figure 3.

Table 1 presents data concerning the present water supply sources of the cities in the local area under discussion. Comparison of the capacities shown in Table 1 with the average daily water requirements in Table 2 shows that the present facilities can nearly meet the average daily demands. However, during peak demand periods these present facilities have been used to their full capacity and will not be adequate during future droughts and other periods of high demand. The Edwards limestone underground aquifer yields water of acceptable quality for water supply, although somewhat harder than is desirable. In contrast, underground water in the vicinity of the other cities contains dissolved mineral constituents in concentrations so high as to make it unacceptable without prohibitively expensive demineralization.



LOCAL AREA

POPULATION TRENDS

U.S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

mfk

FIGURE 3

Table 1

Present Water Facilities - Local Area

City	Present Source	Capacity (mgd)	Quality
Georgetown	2 Wells (Edwards Limestone)	2.16 7/	NO_3>20ppm; high hardness; T.S., Cl, and SO_4 are acceptable.
Taylor	3 Wells (Trinity Sand)	3.70 4/	High SO_4; high F; high T.S.; high Fe; Mg, Cl, and NO_3 are acceptable.
Thrall	2 Wells (Trinity Sand)	.06 11/	No data.
Thorndale	Small reservoir	Unknown	No data.

Description of Lower Brazos River Area

The Brazos River flows in a general southeasterly direction through this area to the Gulf of Mexico. In this area of the Brazos River Basin, the terrain changes from rolling hills in the northern portion to a flat coastal plain surrounding Freeport in the southern section. The slope of the river bed varies from approximately 1.2 ft. per mile near Waco to less than 0.5 ft. per mile near the Gulf. The average flow over 35 years of record at Richmond has been 7,173 cfs, as measured by the U. S. Geological Survey. At Juliff, a city below Richmond, the river has, at times, been dry due to heavy pumping withdrawals. 14/ The records of both gaging stations reflect the effect of regulation by upstream reservoirs.

Within the area, three major tributaries enter the main stem of the Brazos River. Proceeding upstream in order of confluence, these are the Navasota River, Yegua Creek, and Little River. The San Gabriel is a tributary of Little River.

The table-like topography of the area below Waco, along the main channel of the Brazos River, does not afford economical reservoir construction sites. 13/ The flood plain has extensive agricultural development, many highways, railroads, and communities which deter the possible use of this area for reservoirs. For the above reasons, the reservoirs, existing and planned, previously mentioned as being possible surface water sources for the area, are located a number of miles upstream from the major potential water customer, that is, the industrial complex centered in the city of Freeport.

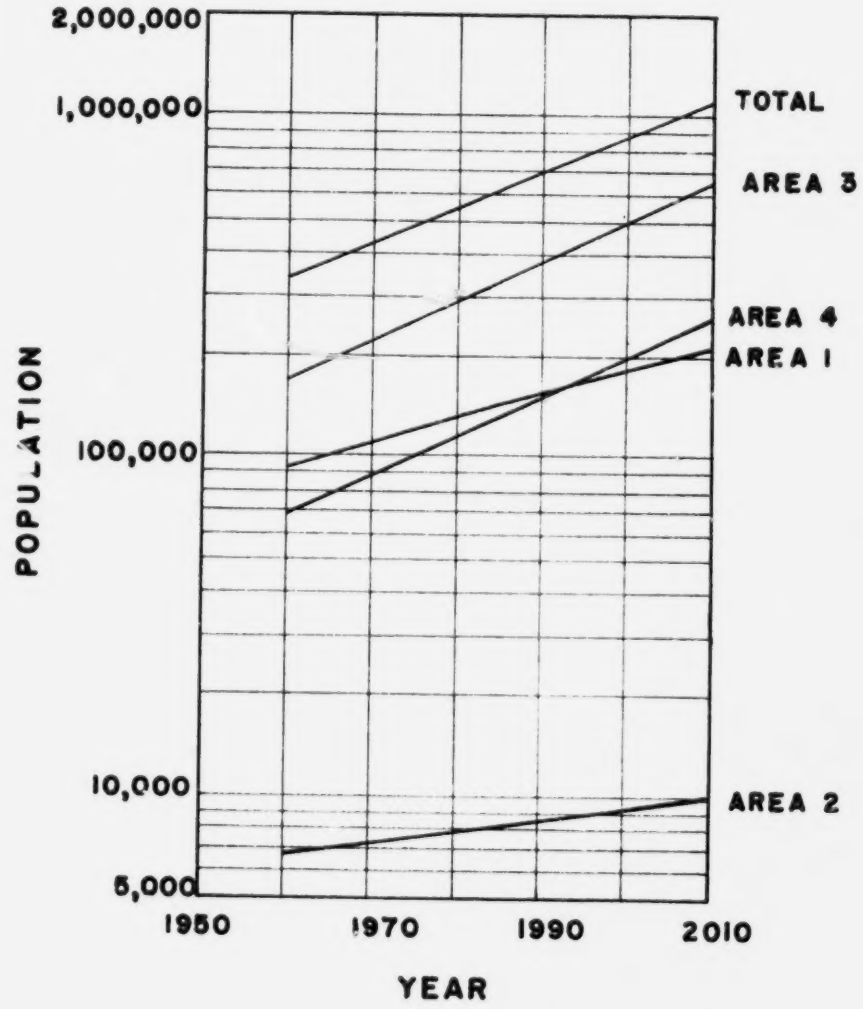
The lower Brazos area is characterized by a mild and fairly uniform climate. The mean annual temperature varies from about 70 degrees in the coastal area to 66 degrees in the vicinity of Waco.[9] From Waco to the Gulf Coast the normal annual rainfall varies from approximately 33 inches to 47 inches.[9] The average length of the growing season ranges from 260 days in the northern portion to 320 days near the coast.[9]

The economy of this area is based upon a wide variety of activities. Agriculture is one of the most important activities and is practiced, to some extent, over the entire area. However, it is most prominent in the northwest and central portions of the study area. The northeast section of the area, surrounding Waco, is underdeveloped industrially, but potential exists.[2] The manufacturing of furniture, apparel, paper, and rubber products also supports the economy of the area near Waco. West of Waco, near Killeen, military installations are an important factor in maintaining that area's economy.[2] In the southern portion of the total study area, the basis for the economy turns from agriculture to the mining of sulphur, the production of oil and gas, oil refining, petrochemical plants, and the extraction of magnesium from seawater.

The future growth of the economy of the area will depend on the growth of its various segments. It is felt that the productivity of the agricultural industry will become stable in the future, but the number of agricultural employees will decrease due to further mechanization in that field of endeavor.[2] It is probable that the industries producing stone, clay, and glass products near Waco will enjoy substantial growth because of the good base already present and because of the availability of supplies of the raw materials necessary for the operation of these industries. The manufacturing activities in the Waco area may also show accelerated growth from the already present base because of the expectation that the markets for these products will expand. Farther south, in the area between Rosenburg and Freeport, it is expected that the petrochemical industries will expand production tenfold by 2010 because of the plants already located there and the plentiful supply of oil and gas in the area. The magnesium extraction could also grow, since all the necessary materials for production are present locally.

Population projections were made for each of the four subdivisions (shown on Figure 1) of the total area. The projected populations given herein include all people who live in organized communities (which would have public water supply systems) and exclude those living outside of such communities. The expected population trends are shown on Figure 4.

In making these forecasts, consideration has been given to published documents,[2,3] historical growth patterns, and information obtained in field investigations. They are, of course, influenced also by the future economic growth just described.



LOWER BRAZOS RIVER AREA

POPULATION TRENDS

U.S. DEPARTMENT OF
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PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 4

PAST AND FUTURE WATER REQUIREMENTS

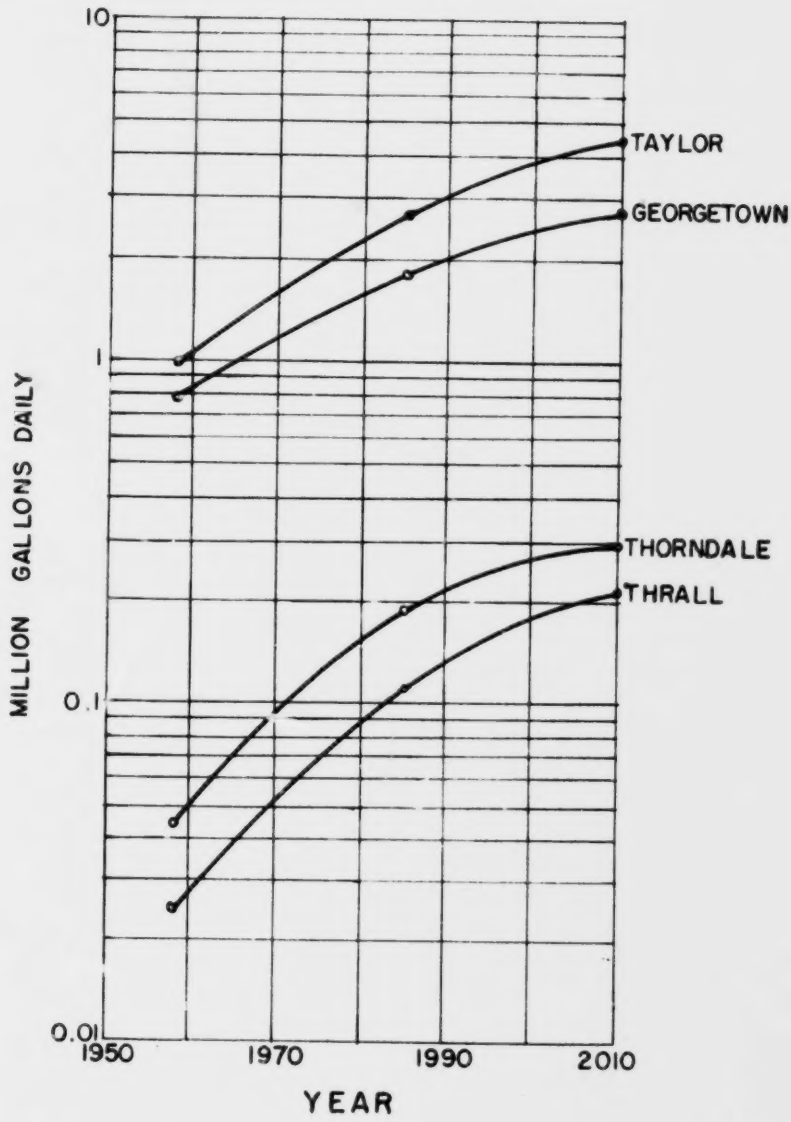
Local Area

Table 2 and Figure 5, following, show the historical and future water requirements of Georgetown, Taylor, Thrall, and Thorndale. The 1958 usage shown was estimated by the city concerned and includes nonindustrial water use plus industrial water use where industry is present. The Public Health Service estimated that these municipalities will have the following amounts of industrial water usage: Georgetown, 20 per cent of total requirement; Taylor, 10 per cent of total; Thrall, no industrial water use; and Thorndale, a constant 0.02 mgd of industrial water usage. The domestic per capita consumption figures shown in Table 2 were arrived at by projecting (for each city) from the present level of per capita use to 180 gpcd, which was considered a common rate of domestic usage for all these cities in the year 2010.

Table 2

Local Area Water Requirements

City	Population	Domestic Use (gpcd)	Total Average Daily Water Requirement (mgd)
		Year 1958	
Georgetown	6,000	---	.789
Taylor	11,000	---	.987
Thrall	550	---	.025
Thorndale	1,300	---	.044
Total	20,450		1.945 mgd
		Year 1985	
Georgetown	9,300	155	1.800
Taylor	17,000	143	2.700
Thrall	990	115	.110
Thorndale	1,400	120	.190
Total	30,940		5.100 mgd
		Year 2010	
Georgetown	12,000	180	2.700
Taylor	22,000	180	4.400
Thrall	1,200	180	.220
Thorndale	1,500	180	.290
Total	39,700		8.210 mgd



LOCAL AREA

WATER REQUIREMENTS

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HEALTH, EDUCATION & WELFARE

PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

FIGURE 5

Lower Brazos River Area

The municipal and industrial water requirements for this area are shown in Table 3 and on Figures 6 and 7. The requirements are indicative of gross intake by water users and do not reflect that a substantial amount of the water used by upstream consumers will be returned to the stream -- eventually to be re-used by downstream users.

The gross requirements were separated into industrial and nonindustrial water uses. Basic industries (the industrial water users) are defined as those that produce on a relatively large scale and sell their products outside the trading area in which they are located -- thus bringing income into that area. Nonbasic industries (nonindustrial water users) are those which supply goods and services only to residents of the trading area, and are supported primarily by the respending of income generated by basic industries.

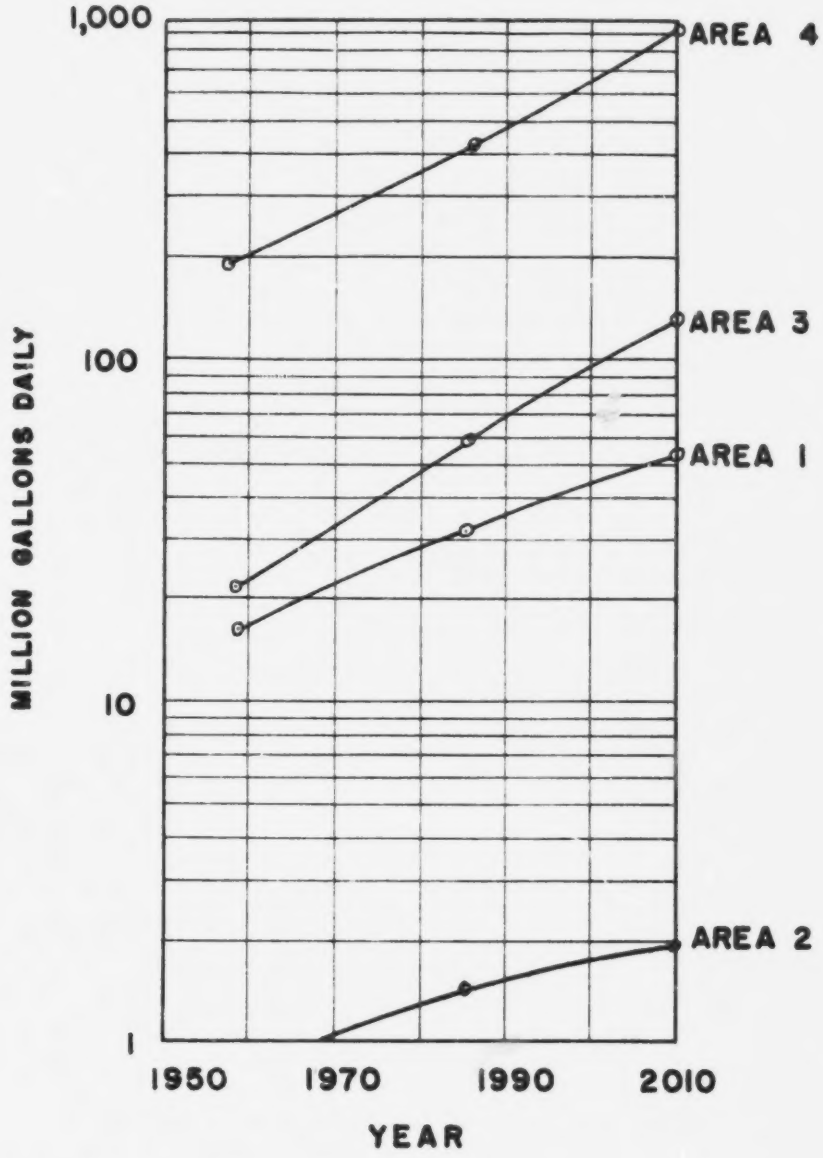
The projected industrial water requirements were obtained after careful consideration of the growth potential in sixteen of the basic industrial categories which use over 90 per cent of the industrial water in the area. The present level of development in each category was compared to development on a national level, so as to obtain an indication of the relative share of the national market that each category holds. Those industrial categories which have less than their share of the national market were projected at a higher rate of growth than expected nationally. Those categories which have more than their share of the national market are expected to maintain their relative percentage of the market in the future. Once a trend in production was assumed for a particular industrial group, a trend in water use was projected. In industries that are large water users this trend, expressed as water requirements per unit of production, was lowered in anticipation of more efficient water use (e.g., cooling towers and other methods of cooling). Data collected in the field were utilized in making these projections. In addition, trends in production and water use as shown in Water Resources Activities in the United States [15] were studied.

The nonindustrial water requirements for this area were prepared through the use of the previously mentioned projected populations and nonindustrial per capita water consumption figures. An average per capita use of 120 gpcd was used for the entire area in 1958 based on data reported to the Texas Health Department by typical cities in the area.

Table 3

Lower Brazos River Area Water Requirements

Sub-Area	Forecast Population	Nonindustrial Use (gpcd)	Average Annual Water Requirement (mgd) Nonindustrial	Industrial
		Year 1958		
1	90,000	120	10.8	5.5
2	6,700	120	0.8	0.01
3	163,000	120	19.6	1.9
4	66,500	120	8.0	181.0
	326,200	Estimated Total Requirements, 1958 - 227.6 mgd		
		Year 1985		
1	143,000	162	23.2	9.7
2	8,300	153	1.3	0.06
3	330,000	162	53.5	4.3
4	136,000	149	20.3	406.0
	617,300	Estimated Total Requirements, 1985 - 518.4 mgd		
		Year 2010		
1	213,000	190	40.5	13.0
2	10,200	170	1.7	0.2
3	660,000	190	125.4	7.3
4	260,000	165	42.9	870.7
	1,143,200	Estimated Total Requirements, 2010 - 1,101.7 mgd		



LOWER BRAZOS RIVER AREA
WATER REQUIREMENTS

U.S. DEPARTMENT OF
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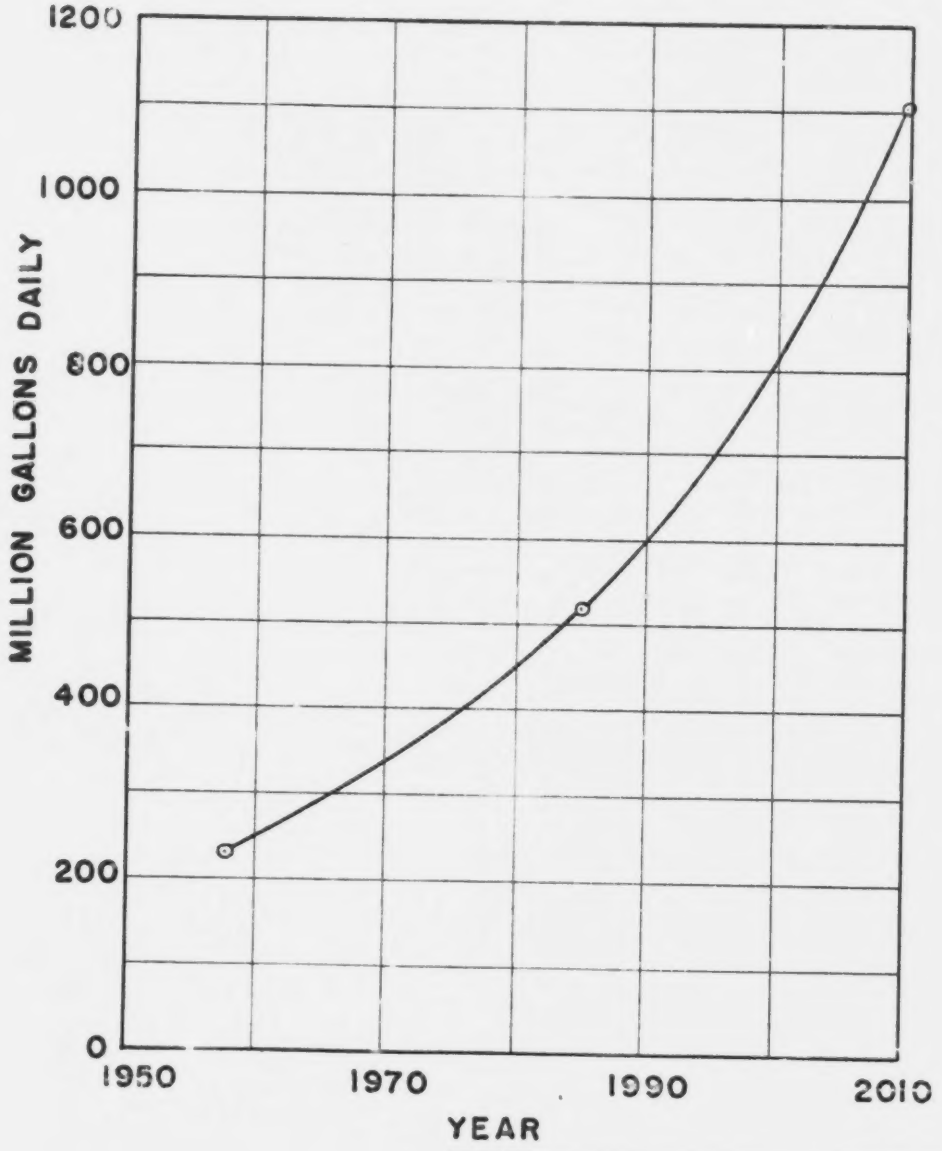
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 6



LOWER BRAZOS RIVER AREA
TOTAL MUNICIPAL & INDUSTRIAL
WATER REQUIREMENTS

U.S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 7

WASTE DISPOSAL

Local Area

The wastes that are discharged from the municipalities in the local area are primarily organic. They are received by Brushy Creek, Mustang Creek, and Willis Creek, which are small tributaries to the San Gabriel River. Granger discharges its wastes after treatment by an Imhoff tank followed by filtration.[10] Since Willis Creek flows into the upper end of the proposed Laneport Reservoir, there is a possibility that a localized pollution problem may develop where this creek empties into the reservoir. Georgetown treats its waste by the method of land irrigation [10] and it is assumed that none of these wastes will reach the San Gabriel River. Round Rock and Thorndale discharge their wastes, after primary treatment,[10] into Brushy Creek; it is felt that these wastes could possibly create a water quality problem in Brushy Creek. However, the effect of these wastes on the San Gabriel River probably will be insignificant. Taylor treats its wastes similarly to Granger, [10] and then discharges them into Mustang Creek, which remains dry much of the time. It is expected that no problem will arise from waste discharges of Taylor. In the future, the municipal wastes discharged into the receiving streams of the local area are not expected to deteriorate the water quality seriously. The methods of waste treatment and treatment plant operation may be expected to improve, leading to higher quality effluents being discharged from these municipalities located in the local area.

Lower Brazos River Area

Due to high concentrations of dissolved solids, principally caused by salt springs and gypsum outcroppings located in the upper reaches of the Brazos River, the water in the main channel is largely unsatisfactory for municipal and industrial use upstream from Whitney Dam. [13] This point will be more fully discussed later in this report.

In the reach of the Brazos River between Waco and a point near river mile 20 (which marks the approximate limit of upstream intrusion into the main channel by sea water) the disposal of treated organic wastes produced by the population in the area, and to some extent by chemical industries, could degrade the water quality -- unless stream flows are maintained at a level where they are able to assimilate the wastes. It is assumed that these organic wastes will be treated for the removal of 90 per cent of the B.O.D. (biochemical oxygen demand). Studies are now underway which will furnish estimates of the amounts of water needed to maintain quality objectives after the wastes are treated. These studies are being made

as a part of a comprehensive consideration of water quality in Texas intrastate streams for the U. S. Study Commission - Texas. Water quality data being collected by the Texas State Health Department will be greatly utilized in these studies.

In the reach of the Brazos described in the preceding paragraph, manufacturing is the most prevalent type of industry. The existing manufacturing processes do not produce large amounts of organic waste. The mineral wastes resulting from future manufacturing, which is expected to be in the primary metals, will (presumably) be treated to such an extent that no adverse stream conditions will be created.

The petrochemical industry is expected to expand tenfold within the next 50 years along the Gulf Coast of Texas. The segment of the Brazos River which will be affected by the large amounts of wastes from this industry will be principally the area where sea water intrudes the fresh water of the Brazos River. The usefulness of this water probably will not be impaired due to quality characteristics, provided the organic wastes from the petrochemical industry are given adequate treatment before being discharged to the river. This is because a major portion of the water used in this area is for cooling purposes for which it is possible to use a water with a relatively high mineral content.

The foregoing statements are subject to qualification in the event that a salt-water barrier is built, to bring the high quality fresh water channel closer to the coast. In that case, it would be necessary to divert the industrial wastes to a separate channel.

THE SAN GABRIEL RIVER AS A SOURCE OF WATER SUPPLY

Quantity of Water Available

The North and South San Gabriel Reservoirs can furnish a combined yield of 26 cfs (16.8 mgd) or a combined yield of 47 cfs (29.7 mgd), depending on which of two possible construction plans is finally adopted. It is estimated that the combined needs of Georgetown, Taylor, Thrall, and Thorndale will be about 8.2 mgd by the year 2010.

The total municipal and industrial water requirements of the entire Lower Brazos River Area, as defined on Figure 1, are expected to be 1,102 mgd by the year 2010. The existing and proposed water supply sources for this area are presented in Table 4. The estimated yields shown for the surface water impoundments are from only the water supply (conservation) storage volume included in each reservoir. A portion of the yields from this conservation storage space is presently allocated to meet irrigation needs. It is infeasible at this time to estimate whether an increase or a decrease will take place in the volume of water allocated to irrigation uses.

Table 4

Existing and Proposed Water Sources
Lower Brazos River Area

Source	Estimated Yield (mgd)
Lake Waco (existing enlarged)	55
Lake Belton (existing enlarged)	105
Stillhouse Hollow Reservoir (proposed)	63
San Gabriel River Project(s) (proposed)	30
Navasota River Project (proposed)	226
Somerville Reservoir (proposed)	34
Ground Water (present and future development)	50
Total	563 mgd

It can be concluded from comparing the expected total water requirements of 1,102 mgd by 2010 with the total estimated yield of 563 mgd, that a demand exists for the maximum feasible amount of municipal and industrial water supply storage that can be economically developed in the proposed project(s) on the San Gabriel River.

Quality of Water

The chemical quality of San Gabriel River water is good at present and should remain so in the future. Data from the Texas State Department of Health indicate that this water meets the Public Health Service standards for drinking water with respect to the concentrations of total dissolved solids, chlorides, and sulfates. A summary of analyses of these data is shown in Table 5.

Table 5

Chemical Quality - San Gabriel River at Georgetown, Texas
(Period of Record - 9/6/57 through 10/19/59)

	Total Solids (ppm)	Chlorides (ppm)	Sulfates (ppm)
Maximum	426	40	31
Minimum	99	4	14
Arithmetic Average	321	25	24

The high mineral concentrations prevalent in the water of the main channel of the Brazos River above Lake Whitney place severe limitations on using it for municipal and industrial purposes. These high concentrations are caused by salt springs located upstream from Lake Whitney. Table 6 shows data collected by the U. S. Geological Survey.

Table 6 1/

Chemical Quality - Brazos River Near Whitney, Texas

Water Year	Mean Daily Discharge (cfs)	Weighted Average Concentrations (ppm)	
		Chlorides	Sulfates
1948-49	1,566	242	172
1949-50	1,520	244	157
1950-51	840	437	260
1951-52	348	332	167
1952-53	141	209	112
1953-54	912	392	198
1954-55	997	374	205
1955-56	1,571	333	255
1956-57	6,213	126	96

As the water in the main stem proceeds downstream, water of higher quality enters the main channel and dilution takes place. The effects of this dilution water, from the tributaries, on the concentrations of chlorides and sulfates may be seen by comparing Table 6 and Table 7. The data shown in Table 7 are also from the U. S. Geological Survey.

Table 7 1/

Chemical Quality - Brazos River at Richmond, Texas

Water Year	Mean Daily Discharge (cfs)	Weighted Average Concentrations (ppm)	
		Chlorides	Sulfates
1948-49	4,645	103	76
1949-50	5,783	87	58
1950-51	1,418	214	134
1951-52	1,820	85	54
1952-53	4,105	31	25
1953-54	2,727	127	72
1954-55	2,168	145	83
1955-56	2,185	260	185
1956-57	15,290	65	54

As shown by the comparison of Tables 6 and 7, the chemical quality of the water in the main channel of the Brazos River improves as the water moves downstream and is diluted by water from tributary streams. Nevertheless, the concentrations of the chlorides and sulfates as far downstream as Richmond are still high enough to produce water of mediocre to poor quality. Unless and until the upstream sources of contamination are eliminated, the quality of Brazos River water will remain at such a level as to make questionable a decision to use this water for municipal and industrial purposes. Studies made jointly by the Brazos River Authority, the Texas State Department of Health, and the U. S. Geological Survey have located the sources of contamination. It is felt that water quality impairment by these sources will be reduced and that the chemical quality of the Brazos River water will improve in the future. This should make possible the utilization of a substantial portion of the runoff in the main stem, which averages about 1,100 mgd above Waco, Texas.

VALUE OF STORAGE

General

The preceding sections of this report have shown the projected water needs of the lower Brazos River area, and the physical feasibility of meeting a part of the need by storage in the multiple-purpose projects under study. The question of economic feasibility leads to consideration of the monetary value, or benefits, of water supply storage.

Efforts to approach this problem on the basis of market value of water have been notably unsuccessful. The cost of impoundment is typically a very small part of the costs of providing water service experienced by a municipal water supply company. Attempts to assign values for water in different uses encounter a wide diversity of uses. For example, household usage alone ranges from drinking water (whose value is immeasurable) to the recreational use of a lawn sprinkler which is turned on, not because the grass needs irrigation, but so that the children can play in it on a hot summer day.

It has been said that the limiting value of works constructed for the improvement of water supply is the maximum amount prudent users would be willing to pay for the improved or augmented service. However, precise measurement of benefits on this basis is difficult, if not impossible. The concept serves to place a ceiling (based on judgment) on the value of storage determined by the "alternative-cost" method.

The Alternative-Cost Doctrine

The 1958 report[8] of the Subcommittee on Evaluation Standards states: "From an overall public viewpoint, a...water supply development will be economically justified if it provides water to meet expected needs at a cost not greater than the cost of the alternative source that would likely be utilized in the absence of the project." Applied to the problem at hand, the stumbling block in this quotation is the word "source".

In the overall picture, it seems certain that the increasing need for firm water supply in the lower Brazos Basin will first be met by additional impoundments of the runoff within the basin. It is not reasonable to assume that this water would be allowed to escape to the Gulf while other water was imported from, say, the Mississippi River. (This is not to be interpreted as ruling out the possibility of interbasin transfers of water.)

Nevertheless, the alternative-cost principle may be applied. Although there is considered to be no alternative water, there are ways to impound it other than by multiple-purpose projects. Unless

otherwise qualified in what follows, the word "Project" will mean the system of five federal reservoirs, Stillhouse Hollow, Somerville, Millican, North San Gabriel and South San Gabriel. In like manner, the word "Alternate" will refer to a hypothetical system of reservoirs which might, in the absence of the Project, be built for water supply only.

Alternative Plan for Water Supply

Meeting the water needs of the study area will apparently require the impoundment of water on each of the major tributaries of the lower Brazos. From a regional standpoint, no single reservoir can be regarded as an alternate to any other, because all will be needed. Hence the decision to look at all five together. The alternate is comprised of five single-purpose dams, located at the same sites as the Corps projects, each having a firm yield equal to that of the project dam. These sites are not the only possible ones for accomplishing the purpose, and validity of the method does not require that alternative sites be the same as project sites. They have been selected for convenience, because of known physical feasibility, and because detailed information for analysis is readily available.

The Fort Worth District Office of the Corps of Engineers furnished estimates of the cost of construction of each single-purpose dam. Table 8 shows these costs and the corresponding annual costs. The latter include operation, maintenance, amortization and interest, using a period of 50 years and an interest rate of 3 per cent.

Each of the aforementioned annual costs is considered to be the minimum annual benefit from water supply storage at the site, from and after the date on which the site might first be needed in the alternative plan.

Sequence of Construction

Although there is no reasonable doubt that all dams in the system would be needed in less than 50 years, it is equally clear that not all are needed now. For subsequent use, it is necessary to assume a sequence of construction and date of first utilization of each dam in the alternative system. Mathematically, there are 120 possible combinations of the five dams. Trial calculations to establish extremes indicate that a range of combined present values, on the order of 20 per cent, would result from different combinations.

The problem of adopting a schedule of sequence and date of construction involves a number of factors. There is a wide diversity in the sizes of individual reservoirs, with yields ranging from 11 to 226 mgd. As might be expected, the unit cost per thousand gallons of potential yield varies inversely with the capacity.

Table 8

Alternative Costs and Present Value

	Stillhouse Hollow	Somerville	North San Gabriel	Millican	South San Gabriel	Sum or Average
Order of Construction	(1)	(2)	(3)	(4)	(5)	
Yield, mgd	63	34	19	226	11	353
Construction Cost, Single-Purpose Alternative	$12,220,000	$11,220,000	$8,250,000	$27,060,000	$5,860,000	
Annual Capital Cost (50 years @ 3%)	475,000	436,000	321,000	1,053,000	228,000	
Annual O & M Cost	40,000	30,000	38,400	57,000	37,600	
Combined Annual Costs	$515,000	$466,000	$359,400	$1,110,000	$265,600	
Unit Costs, Cents/1,000 gal.	2.24	3.76	5.18	1.35	6.62	
Year of First Need	1960	1964	1968	1970	1987	
Years Until Utilized	0	4	8	10	27	
Present Worth Factor	1.000	0.888	0.789	0.744	0.450	
Present Annual Value	$515,000	$414,000	$284,000	$826,000	$120,000	$2,159,000
Present Benefits in ¢/1,000 gal. yield	2.24	3.34	4.10	1.00	2.99	1.68

The sequence which gives the lowest present (1960) value of all future costs, is that of scheduling dams in decreasing order of unit cost, i.e., from largest to smallest size. However, it is believed that this is not necessarily the sequence most likely to be chosen. Building the largest dam (Millican) first would give the least favorable capacity factor (ratio of actual use to capacity) over the longest period of time.

At the opposite extreme might be a sequence from smallest to largest size. Reference to Table 8 will show that the smallest, South San Gabriel, would yield 11 mgd at a unit cost of 6.62 cents per thousand gallons. It seems likely that this unit cost would be higher than the ceiling which the prudent user, mentioned in the introduction to this chapter, would be willing to pay. The engineer, making today a plan for meeting future water supply needs, would probably feel that it might some day be necessary to pay a price that high. But, more than likely, he would defer that project as long as possible.

To a somewhat lesser degree, the foregoing statements would apply to the North San Gabriel site. There, a reservoir to yield 19 mgd would cost 5.18 cents per 1,000 gallons. However, at this point, another facet of the problem should be considered.

A decision to defer construction of the dam on any one of the tributaries would involve the question of present need in the area immediately downstream on that tributary. Detailed study of all such local areas has not been completed at this writing. Local areas which have been investigated are Georgetown and Taylor on the San Gabriel, and Bryan-College Station and Navasota for the Navasota River. The present, and probable future, needs of Georgetown and Navasota can be met by ground water. Estimates of relative transmission costs indicate that Bryan-College Station could obtain water more economically from the main stem of the Brazos than from the Navasota River.

This leaves the Taylor area, in which the ground water is too highly mineralized for satisfactory use. This poses a problem for Taylor for which no answer is readily apparent, unless storage can be provided in one of the San Gabriel multiple-purpose reservoirs, at a cost substantially lower than the figures of 5 to 7 cents per 1,000 gallons. Otherwise, it is believed that some expedient would be found for meeting the relatively small needs of Taylor which would not require expenditure of several million dollars for a dam. For example, good quality ground water is available (from the Edwards formation) about eleven miles west of the city. Nevertheless, in consideration of the local area needs, especially Taylor, the North San Gabriel project has been inserted in the sequence for construction by 1968.

Translation of Alternative Costs to Multiple-Purpose Project Benefits

In spite of complexities and uncertainties, it is essential to formulate an alternative plan for the objective of determining the value of storage in the project. To this end, the sequence of construction of the alternative dams has been assumed to be as indicated in Table 8. The current year (1960) has been selected as the common time base, to which all future benefits are adjusted.

The adjustment of future benefits to present date was made by the method of capitalized costs, as described by Woods and DeGarmo in Introduction to Engineering Economy[16]. Fundamental to the method is the assumption that the physical life of a reservoir (as distinguished from amortization period) is indefinite, but would be longer than 50 years. An interest rate of 3 per cent was used for discounting. Superimposing the yields on a graph of future water requirements, in the adopted sequence, gives the date of first utilization of each reservoir (see Figure 8).

The combined present value of storage in the alternative plan is about 56 million dollars. For a combined yield of 353 mgd, this reduces to a unit value of 1.68 cents per thousand gallons.

It is therefore concluded that the present value (1960) of annual benefits from storage in the several reservoirs of the project will average at least 1.68 cents per thousand gallons of yield. Suggested individual benefits which make up this average are shown in Table 8.

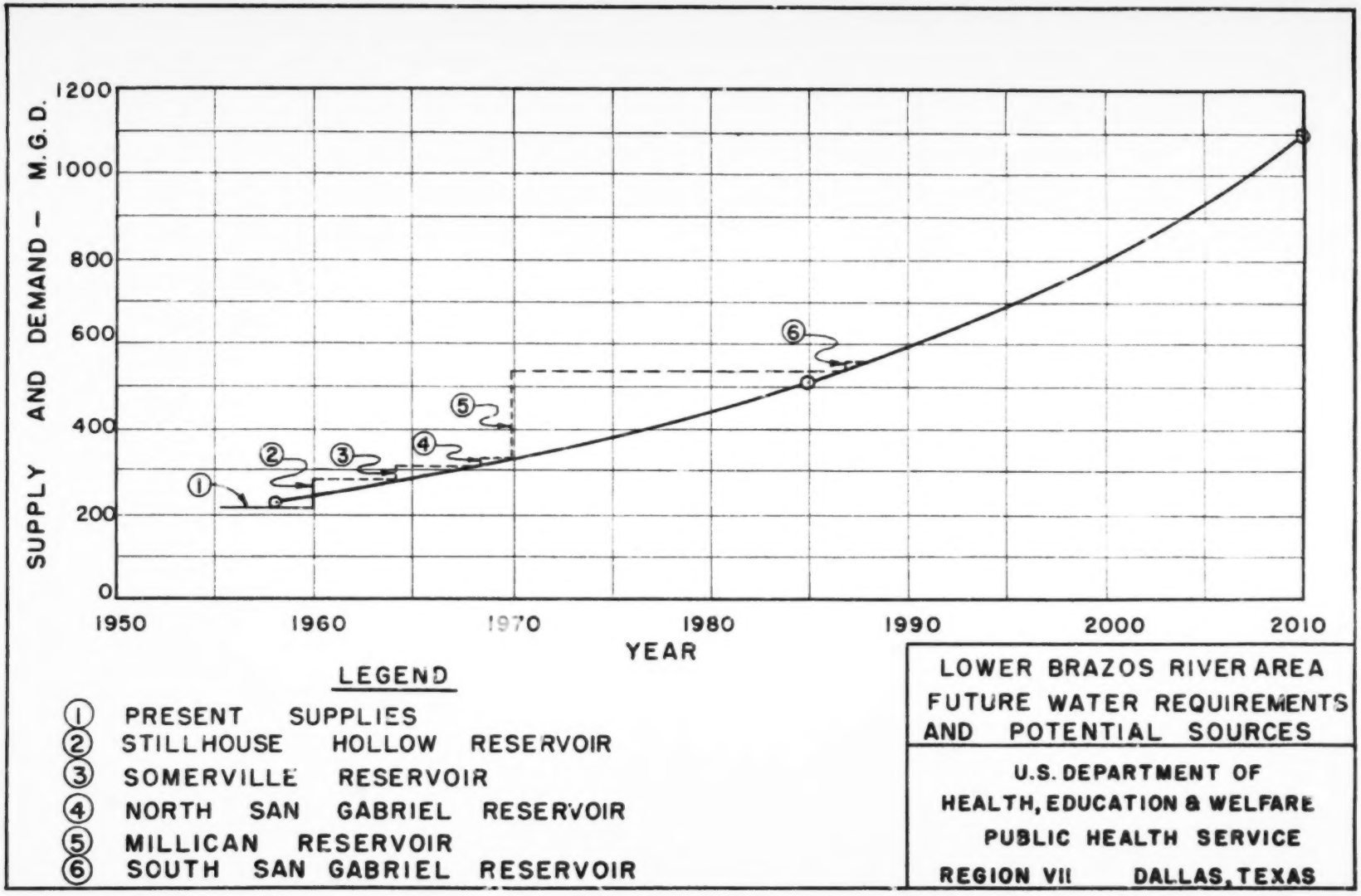

SUPPLY AND DEMAND — M.G.D.
1200
1000
800
600
400
200
0
1950
1960
1970
1980
1990
2000
2010
YEAR
①
②
③
④
⑤
⑥
LEGEND
① PRESENT SUPPLIES
② STILLHOUSE HOLLOW RESERVOIR
③ SOMERVILLE RESERVOIR
④ NORTH SAN GABRIEL RESERVOIR
⑤ MILLICAN RESERVOIR
⑥ SOUTH SAN GABRIEL RESERVOIR
LOWER BRAZOS RIVER AREA
FUTURE WATER REQUIREMENTS
AND POTENTIAL SOURCES
U.S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 8

BIBLIOGRAPHY

1. Brazos River Authority. Unpublished minutes of Brazos River Authority Water Quality Conference. Nov. 7, 1958.

2. Bureau of Business Research, University of Texas. Water for the Future (Texas Gulf Basin). Bureau of Reclamation, Aug. 31, 1956 (Supplement Aug. 31, 1957); 5 vols.

3. Bureau of Business Research, University of Texas. Water Requirements Survey for Texas (Bulletin 5910). Texas Board of Water Engineers, July, 1959; 76 pp.

4. Freese and Nichols, Consulting Engineers. Report on Taylor, Texas Water Supply. January 1959; 66 pp.

5. Gloyna, E. F.; Hermann, E. R.; and Drynan, W. R. Water Re-Use. Bureau of Reclamation, June 30, 1957; 147 pp.

6. Ground Water Resources of Brazoria County, Texas. Texas Board of Water Engineers, 1947; 25 pp.

7. Guyton, W. F. and Associates, Consulting Ground-Water Hydrologists. Ground Water Conditions in the Vicinity of Georgetown, Texas. Mar. 1957; 25 pp.

8. Proposed Practices for Economic Analysis of River Basin Projects. Subcommittee on Evaluation Standards, May, 1958; 56 pp.

9. Texas Almanac and State Industrial Guide. Dallas; Dallas Morning News, 1952; 671 pp.

10. Texas State Department of Health. Inventory of Municipal and Industrial Waste Facilities for the State of Texas. U. S. Public Health Service, 1958, unpublished.

11. Texas State Department of Health. Inventory of Municipal Water Facilities for the State of Texas. U. S. Public Health Service, 1958, unpublished.

12. Seelye, E. E. Data Book for Civil Engineers, Specifications and Costs. Wiley and Sons, New York, Vol. 2; 1957.

13. Summary of the Master Plan. Brazos River Authority, Sept. 1957; 37 pp.

14. U. S. Congress. Senate. Water Developments and Potentialities of the State of Texas. 85th Cong., 2nd Sess., Senate Doc. 111 (1958).

15. U. S. Congress. Senate. Water Resources Activities in the U. S. 86th Cong., 2nd Sess., Senate Committee on National Water Resources. Committee print No. 8.

16. Woods, B. M. and DeGarmo, E. P. Introduction to Engineering Economy. The Macmillan Company, New York, 2nd ed., 1957.